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PHOSPHORUS MANAGEMENT EFFECTS ON P FRACTIONS IN SOILS AS NUTRITION FOR RICE

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ABSTRACT

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An incubation study in the lab and a pot experiment were conducted to know the distribution of native and applied P in the soils and its effect on rice (BRRI dhan28). There were two treatments namely control and P amendment (200 mg kg^{-1}) maintaining. Three replications were used in the experiments. The texture of Old Brahmaputra Floodplain and Bangladesh Agricultural University farm soils, Khulna and Madhupur soils, Bogra, Haji Mohammad Danesh Science and Technology University farm and Kushdaha soils were silt loam, loam, silty clay loam, sandy loam and silty clay, respectively. The initial status of labile P, Fe/Al-P and Ca/Mg-P of the different soils were 3.16 to 15.36, 16.48 to 86.42 and 10.59 to 68.18 mg Kg^{-1}, respectively. Addition of 200 mg P per kg soil increased the labile P, Fe/Al-P and Ca/Mg-P ranging from 2.23 to 35.60, 26.95 to 68.33 and 18.34 to 40.73%, respectively over the initial status. Due to cropping, a remarkable depletion was found in post-harvest soils in non-treated pots and the depleted amount ranged from 13.65 to 28.73, 1.46 to 8.33 and 0.63 to 2.87% for labile P, Fe/Al-P and Ca/Mg-P, respectively over the initial status. In treated pots, the depletion of labile P, Fe/Al-P and Ca/Mg-P varied from 1.96 to 4.10, 0.95 to 5.01 and 0.35 to 1.97 mg kg^{-1}, respectively while percent use efficiency were 61.57 to 745.45, 28.19 to 92.40 and 10.17 to 42.27%, respectively. Application of P increased the dry matter yield of rice in all the selected soils.

***Key words**: phosphorus, iron, aluminum, calcium, HYV rice, soil*

INTRODUCTION

Most of the rice yield comes from high yielding variety (HYV) of rice. Most of the soils are getting exhausted because of continuous growing HYV rice and injudicious fertilizer management. This is resulting in problems of P, K, and S deficiency in soils along with inherited N deficiency (Ali *et al*. 1997; Saleque *et al*. 1998a; Saleque *et al*. 1998b). With increasing demand of agricultural production and as the peak in global production will occur in the next decades, phosphorus (P) is receiving more attention as a nonrenewable resource (Cordell *et al*. 2009). Phosphorus (P) is an essential element for plant growth. It is very important in the early vegetative growth stages (Slaton *et al*. 2002). Rice plants that are deficient in P are stunted and dirty-dark green and they have erect leaves, relatively few tillers and decreased root mass (Dobermann and Fairhurst, 2000). When P fertilizers are applied in soils, they are dissociated into ionic forms and the concentration of the ions in soil solution is increased. One unique characteristic of P is its low availability due to slow diffusion and high fixation in soils. The amount of P ions fixed by soil particles is not easily available to the plants. This fixation is higher in acidic and calcareous soils where higher amount of P fertilizers is needed to meet up the requirements of growing crops.

There are two categories of P in soils such as organic P and inorganic P. Soil organic P forms exist mostly in humus and other organic materials are not readily available to plants. Inorganic P can be grouped into five general categories namely iron (Fe) phosphates, aluminum (Al) phosphates, calcium (Ca) phosphates, reductant soluble phosphates (soluble under reduced soil conditions), and occluded Fe and Al phosphates (phosphate covered with Fe_2O_3 or AlO_3 which are not available until the covering is removed) (Johnston 2001). When P is added in neutral soil, it forms Ca and Mg phosphate minerals and a part is adsorbed on the surface of clay particles; this adsorbed P readily supplies P to the soil solution for plant uptake which is also referred to as labile P (Johnston 2001). Phosphorus must be in the soluble orthophosphate form (HPO_4^{2-}, $H_2PO_4^{-}$) to be taken up by rice and all other plants (Snyder 2002). After application, when P is fixed with Al, Fe, Mg, Ca and other elements, they contribute P in soil solution slowly. They have very low solubility and not readily available for plant uptake. All of the forms of P become available when the pH of soil is neutral. Manure can be applied to soil as a source of P fertility. The total P content in manure is very variable and nearly 70% of total P in manure is labile. Flooding (saturation with water) generally increase the availability of P to rice crops. The increase in P availability for rice under flooded conditions involves the reduction of ferric (Fe^{3+}) phosphate to ferrous (Fe^{2+}) phosphate and some dissolution of Ca phosphates at higher CO_2 levels in the soil solution. In flooded soil, regardless of its original pH before flooding, the pH will approach neutrality (pH 6.5 to 7.5) where the pH of alkaline soils declines and the pH of acid soils increase (Snyder 2002). Liming in the acid soils increase the pH and increse the P availability. Only 15-30% of applied fertilizer P is taken up by crops in the year of its application (Syers *et al*. 2008). So, proper management of soils has become a prime necessity for sustained P fertility and yield of crops. In the knowledge of soil, P fractions is important as it will assist us in assessing the fertility status and fate of P. Considering the above fact present study was undertaken with the following objectives: i) to see the distribution of applied P into different forms in soils from different Agro-Ecological Zones (AEZs); ii) to see the changes in different forms of soil P due to uptake by plants and iii) to see the effects of applied P on the dry matter yield of rice.

MATERIALS AND METHODS

Experimental site

In the research, incubation study and pot experiment were conducted at the field laboratory and net house of the Department of Soil Science, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh. Geographically, the experimental site stands at 24.75^0N latitude and 90.50^0E longitude at the height of 18m above the mean sea level.

Soil samples

Seven soil samples were collected at a depth of 0-15 cm from seven different places of six Agro-ecological Zones (AEZs) of Bangladesh. The seven places were Khulna (Ganges Tidal Floodplain), Bogra (Level Barind Tract), Haji Mohammad Danesh Science and Technology University (HSTU) farm (Old Himalayan Piedmont Plain), Kushdaha (North Eastern Barind Tract), Madhupur (Madhupur Tract), Bangladesh Agricultural University (BAU) farm (Old Brahmaputra Floodplain-non flooded), Farmers' field (Old Brahmaputra Floodplain (OBF)-flooded).

Analysis of samples

Initial soil samples were analyzed for both physical and chemical properties such as soil texture, soil pH, electrical conductivity (EC), organic matter (OM), total N, available P, exchangeable K and available S. Particle size analysis of soil was done by hydrometer method (Black 1965) and the textural class was determined by plotting the values for % sand, % silt and % clay in the Marshall's triangular coordinates following the USDA system. Soil pH was determined using glass electrode pH meter in soil: water suspension of 1:2.5 (Jackson 1962). EC of soil samples was determined by an EC meter using soil water suspension of 1:5 (Page *et al.* 1982). Organic carbon was determined by wet oxidation method as described by Walkley and Black (1934) and the organic matter content was calculated by multiplying the obtained organic carbon with the van Bemmelen factor of 1.73 (Piper 1995). Total N was determined by Semi-micro Kjeldahl method (Bremner and Mulvaney, 1982) and available P was determined colorimetrically by stannous chloride ($SnCl_2$) method (Olsen *et al.* 1954). Exchangeable K and available S were determined by flame photometer (Black 1965) and a spectrophotometer method (Page *et al.* 1989) respectively.

Incubation test

For incubation study, 200ppm of P was added in 100gm of each soil in 250ml plastic bottles and control bottles were run with the treated soils which were incubated at room temperature for 60 days and then soils were air dried, ground and preserved for fractionation study.

Labile P was extracted from 2g air-dried soil sample by shaking 2 hours with 20ml 1M NH_4Cl solution at pH 7.0 following the method of Jackson (1973). The extracted phosphorous was determined by developing blue color using $SnC1_2$ and measuring the intensity of color colorimetry at 660 nm wave length. Fe/Al-P was extracted from 2g air dried soil sample by shaking17 hours with 20ml 0.1N NaOH solution following the method of Jackson (1973). The extracted phosphorus was determined by developing blue color using $SnC1_2$ and measuring the intensity of color colorimetry at 660 nm wave length. The labile P was subtracted from the results obtained with NaOH to get Fe/Al-P. Ca/Mg-P was extracted from 2g air dried soil sample by shaking 24 hours with 20ml 0.5M HCI solution following the method given by Jackson (1973). The extracted P was determined by developing blue color using $SnCl_2$ and measuring the intensity of color colorimetry at 660nm wave length. The labile P was subtracted from the results obtained with HCl to get Fe/Al-P.

Pot experiment

For pot preparation, 1 kg soil was taken in each of 42 earthen pots. BRRI dhan28 was used for the experiment as the rice variety. Three healthy seedlings/hill/pot of thirty five day old were transplanted in the pots on 31 December, 2013. There were two treatment combinations in the experiment e.g. control and P (25 kg P ha^{-1}). The experiment was replicated thrice. N, P, S and Zn were applied as basal dose. Full doses of chemical fertilizers *viz.* TSP (25 kg P ha^{-1}), MoP (100 kg K ha^{-1}), gypsum (20 kg S ha^{-1}), zinc oxide (2 kg Zn ha^{-1}) were added to soils. Urea was applied in three equal splits at 0, 20, 45 days after transplanting (DAT) where the dose of urea for each split was 45 kg N ha^{-1}. Intercultural operations such as irrigation and drainage (maintaining 1 cm height on soil surface), weeding etc were performed when needed. The rice plants of each pot were harvested and colllected at 70DAT on 20 March, 2014. Then plant samples were cleaned and air dried. At the same time soil samples were collected also. Then samples were made free from plant roots, air dried ground and prepared for analysis.

Plant sample

The air dried plant samples (straw) were dried in an oven at 65^0C for about 48 hours, were then grounded in a grinding machine and stored in paper bags for determination of P. A sub- sample of plant samples weighing 0.5 g was transferred into a dry clean digestion vessel. 10ml of acid mixture (HNO_3:$HClO_4$=5:1) was added to it. After leaving for a while, the vessels were heated at a temperature slowly raised to 200^0C. Heating was momentarily stopped when the dense white fumes of $HClO_4$ occurred. The contents of the flask were boiled until they become sufficiently clear and colorless and the digest was used for estimating P. Then the concentration of P in the digest was determined by similar method as described in case of soil analysis.

Experimental design

The experiment was laid out with two treatments in Randomized Complete Block Design with three replications. The analysis of variance for dry matter yield of the crop was performed by using MSTAT-C program. The difference between the treatment means was estimated following the F-test. Mean comparisons of the treatments were made by the Duncan's Multiple Range Test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Distribution of labile P in treated and non treated soils were studied in incubation study (Table 1). Concentration of labile P showed wide variation where the highest and the lowest amount of labile P were in Khulna (15.36 mg kg^{-1}) and OBF (3.16 mg kg^{-1}) soils. The status of HSTU farm soil (14.92 mg kg^{-1}) was very close to Khulna soil (15.36 mg kg^{-1}) and remarkably higher than other soils. A remarkable increase was found in labile P content in all soils due to addition of 200 mg P kg^{-1} soil ranging from 10.03 to 86.55 mg kg^{-1} soil. The increasing range was 59.12 to 1143.04% across the soils over the initial status. The transformation of added P to labile P also varied considerably ranging from 2.23 to 35.60% among the soils. The highest and the lowest transformation were in Khulna and Kushdaha soils.

Table 1. Distribution of labile P in treated and non treated soils (mg kg^{-1})

Soils	Initial	Treated soil	% increase over initial	Transformation of added P (%)
Kushdaha	5.57	10.03	80.07	2.23
HSTU farm	14.92	23.74	59.12	4.41
Khulna	15.36	86.55	463.48	35.60
Madhupur	9.28	16.09	73.38	3.41
BAU farm	5.13	41.16	702.34	18.02
OBF	3.16	39.28	1143.04	18.06
Bogra	10.42	69.34	565.45	29.46

The initial Fe/Al-P of the soils under incubation study also showed wide variations across the collected soils ranging from 16.48 to 86.42 mg kg^{-1} (Table 2). The highest amount was observed in HSTU farm soil followed by Madhupur soils and the lowest one was found in Khulna soil. The Fe/Al-P of Khulna soil was the lowest although it’s labile P was the highest. Due to addition of P, the Fe/Al-P increased remarkably ranging from 95.00 to 327.06% across the soils over the initial status. A remarkable amount of added P was transformed into Fe/Al-P ranging from 26.95 to 68.33%. The highest and the lowest amount of added P was transformed into Fe/Al-P in Kushdaha and Khulna soils respectively.

Table 2. Distribution of Fe/Al- P in treated and non treated soils (mg kg^{-1})

Soils	Initial	Treated soil	% increase over initial	Transformation of added P (%)
Kushdaha	48.36	185.02	282.59	68.33
HSTU farm	86.42	168.52	95.00	41.05
Khulna	16.48	70.38	327.06	26.95
Madhupur	67.10	177.79	164.96	55.35
BAU farm	27.24	87.97	222.94	30.37
OBF	18.75	73.74	293.28	27.50
Bogra	48.14	115.49	139.90	33.68

The variation in Ca/Mg-P in initial soils under incubation study ranged from 10.59 to 68.18 mg kg^{-1} (Table 3). The highest amount was observed in OBF-flooded soil which was strongly higher than other soils and the lowest amount was in Kushdaha soil. Due to Addition of P to these soils the status of Ca/Mg-P increased ranging from 49.60 to 149.63 mg kg^{-1}. The percent transformation of added P to Ca/Mg-P ranged from 18.34 to 40.73%. The highest transformation was in OBF soil (40.73%) and the lowest was in HSTU farm soil (18.34%). The transformation of added P to Ca/Mg-P was almost similar in Khulna and BAU farm soils.

Table 3. Distribution of Ca/Mg- P in treated and non treated soils (mg kg^{-1})

Soils	Initial	Treated soil	% increase over initial	Transformation of added P (%)
Kushdaha	10.59	49.60	368.37	19.51
HSTU farm	14.75	51.43	248.68	18.34
Khulna	32.73	107.69	229.03	37.48
Madhupur	27.71	97.86	251.79	35.08
BAU farm	64.87	139.4	114.89	37.27
OBF	68.18	149.63	119.46	40.73
Bogra	11.29	67.13	494.60	27.92

In pot experiments, results showed that due to addition of P an amount of 0.28 to 4.45 mg P kg^{-1} soil was transformed into labile P. A remarkable depletion of Labile P was observed in post-harvest soils ranging from 1.96 to 4.10 mg kg^{-1} soils (Table 4). This indicates that the amount of Labile P taken up by plants was much higher than the added amount (0.28-4.45 mg kg^{-1}) in all of the soils except BAU farm and Khulna soils. The highest and the lowest amounts of Labile P were taken up from the HSTU farm and Kushdaha soils respectively. The percent use efficiency of added P varied from 61.57 to 745.45%.

Table 4. Changes in Labile P in treated soils due to cropping (mg kg^{-1})

Soils	Initial	Added	Total	Post-harvest	Amount used	Use efficiency of added P (%)
Kushdaha	5.57	0.28	5.85	3.89	1.96	700.00
HSTU farm	14.92	0.55	15.47	11.37	4.10	745.45
Khulna	15.36	4.45	19.81	17.07	2.74	61.57
Madhupur	9.28	0.43	9.71	6.92	2.79	648.84
BAU farm	5.13	2.50	7.63	5.31	2.32	92.80
OBF	3.16	2.26	5.42	3.02	2.40	106.19
Bogra	10.42	3.68	14.1	10.23	3.87	105.16

For Fe/Al-P, after P addition, an amount of 3.37 to 8.54 mg of added P kg^{-1} soil was transformed into Fe/Al-P across the soils (Table 5). The highest and the lowest depletion of Fe/Al-P were observed in Kushdaha and Khulna soils while use efficiency of added P ranged from 28.19 to 92.40%. In Khulna soil, the use efficiency of added P and the used amount both showed the lowest status.

Table 5. Changes in Fe/Al- P in treated soils due to cropping (mg kg^{-1})

Soils	Initial	Added	Total	Post-harvest	Amount used	Use efficiency of added P (%)
Kushdaha	48.36	8.54	56.9	51.89	5.01	58.67
HSTU farm	86.42	5.13	91.55	87.80	3.75	73.10
Khulna	16.48	3.37	19.85	18.90	0.95	28.19
Madhupur	67.10	6.91	74.02	71.32	2.70	39.07
BAU farm	27.24	3.79	31.04	28.83	2.21	58.31
OBF	18.75	3.44	22.19	20.35	1.84	53.49
Bogra	48.14	4.21	52.35	48.46	3.89	92.40

In case of Ca/Mg-P, after addition of P an amount of 2.44 to 5.48 mg of added P kg^{-1} soil was transformed into Ca/Mg-P across the soils (Table 6). As a result of plant uptake, the highest and the lowest values in post-harvest soils were observed in OBF-flooded (71.98 mg kg^{-1}) and Kushdaha (12.45 mg kg^{-1}) soils respectively. But in percent use efficiency of added P, the highest and the lowest value was found in BAU farm (42.27%) and Khulna soils (10.17%) respectively. BAU farm soil showed the highest status both in used amount (1.97 mg kg^{-1}) and use efficiency of added P (42.27%).

Table 6. Changes in Ca/Mg-P in treated soils due to cropping (mg kg^{-1})

Soils	Initial	Added	Total	Post-harvest	Amount used	Use efficiency of added P (%)
Kushdaha	10.59	2.44	13.03	12.45	0.58	23.77
HSTU farm	14.75	5.48	20.23	19.17	1.06	19.34
Khulna	32.73	3.44	36.17	35.82	0.35	10.17
Madhupur	27.71	4.38	32.09	31.03	1.06	24.20
BAU farm	64.87	4.66	69.53	67.56	1.97	42.27
OBF	68.18	5.09	73.27	71.98	1.29	25.34
Bogra	11.29	3.49	14.78	14.36	0.42	12.03

Dry matter Yield

The dry matter yields of BRRI dhan28 in non-treated pots varied considerably ranging from 2.08 to 4.40 g pot^{-1} in different soils under study (Fig. 1). The dry matter yield was highest in Bogra soil followed by Kushdaha and then HSTU farm soils. The lowest value was found in OBF-flooded soil and then Madhupur soil. The dry matter yields of BAU farm soil were significantly higher than Khulna, Madhupur and OBF soils but lower than rest of the soils. A remarkable increased amount of dry matter yields were found in treated pots over the non-treated amount. A significant variation was found among the yields ranging from 3.77 to 5.48 g pot^{-1}. The yield of Kushdaha soil was next to Bogra but they were statistically similar. The highest amount was found in HSTU farm soil (5.48 g pot^{-1}). It was statistically similar to Bogra soil but higher than all other soils. The yield of

Kushdaha soil was next to Bogra but they were statistically similar. They were followed by OBF and then Madhupur soils. Lower response of added P on dry matter yield was found in Khulna and BAU farm soils.

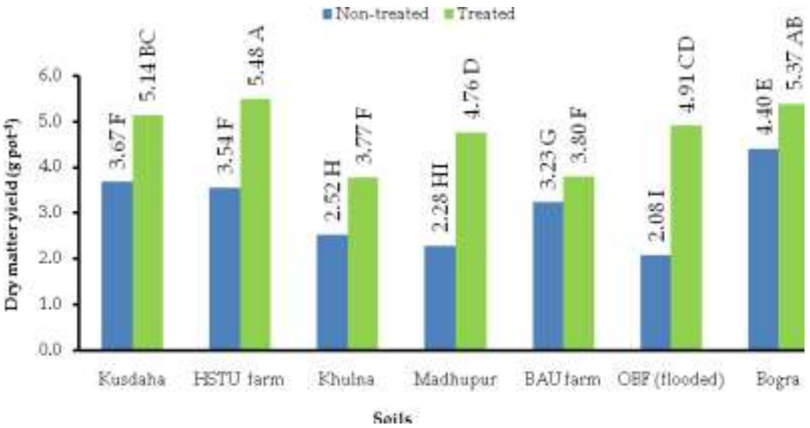

Fig. 1. Interaction (soil type & treatments) effects on dry matter yield of rice plants (BRRI dhan28)

The soil effects on the dry matter yield showed the highest value in Bogra soil (4.89 g pot^{-1}) (Fig. 2). This was followed by HSTU farm and Kushdaha soils which were statistically similar. The values of Madhupur, BAU farm and OBF soils were statistically similar and lower than Bogra, HSTU farm and Kushdaha soils. The lowest value was obtained from Khulna soil (3.15 g pot^{-1}).

Fig. 2. Soil effects on dry matter yield of rice plants

The average dry matter yield of treated pots (4.75 g pot^{-1}) was significantly higher than non-treated pots (3.10 g pot^{-1}) mean that dry matter yield will definitely increase if P is added to the soil though the rate may vary according to soil type (Fig. 3).

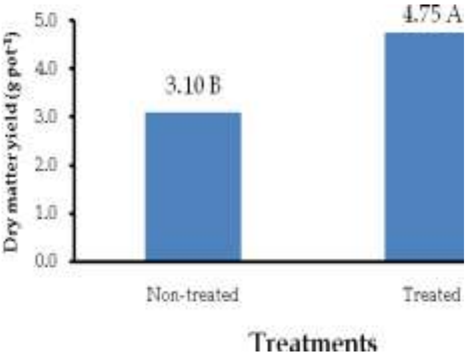

Fig. 3. Treatment effects on dry matter yield of rice plants

A significant variation was observed in P concentration of the plants in non-treated pots ranging from 856.8 mg kg^{-1} to 1235.22 mg kg^{-1} (Fig. 4). The highest amount of P concentration was found in Kushdaha soil (1235.22 mg kg^{-1}) followed by Madhupur (1153.11 mg kg^{-1}). The lowest amount was found in OBF-flooded soil (856.80 mg kg^{-1}) followed by Khulna (881.79 mg kg^{-1}). In treated pots, the P concentration of the plants increased where the highest and the lowest values were found in Kushdaha (1288.77 mg kg^{-1}) and Khulna (963.90 mg kg^{-1}) soils, respectively. Results from P uptake by plants, the Khulna soil also showed the lowest value in treated soil and second lowest value in non-treated soil.

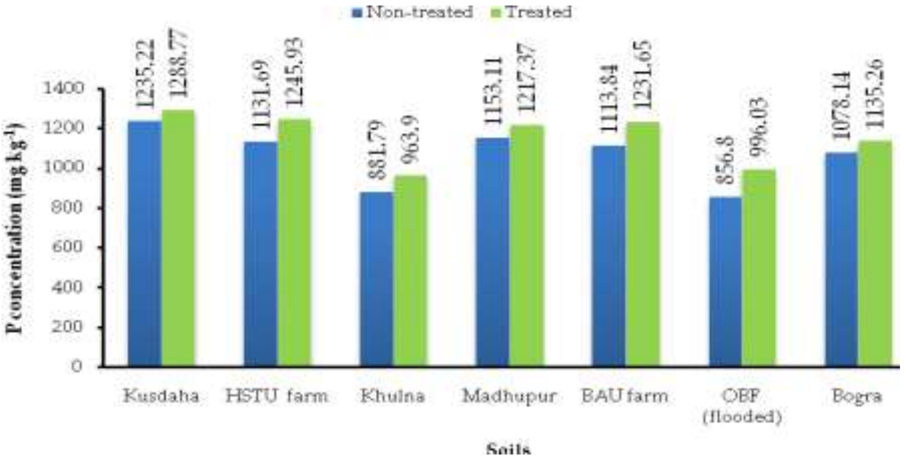

Fig. 4. Effects of P on P concentration in rice plants taken up from different soils

The results of the values of P taken up by plants in non-treated pots varied from 1.78 to 4.74 mg pot^{-1} (Fig. 5). The values of Khulna, Madhupur and OBF soils were close and remarkably lower than rest of the soils. The highest and the lowest amounts were taken up from Bogra and OBF soils, respectively. The P uptake significantly increased in the treated pots varied from 3.63 mg pot^{-1} to 6.83 mg pot^{-1}. The highest amount was found in HSTU farm soil followed by Kushdaha (6.62 mg pot^{-1}) soil. The Khulna soil showed the lowest value in treated soil but in non-treated soil its value was second lowest.

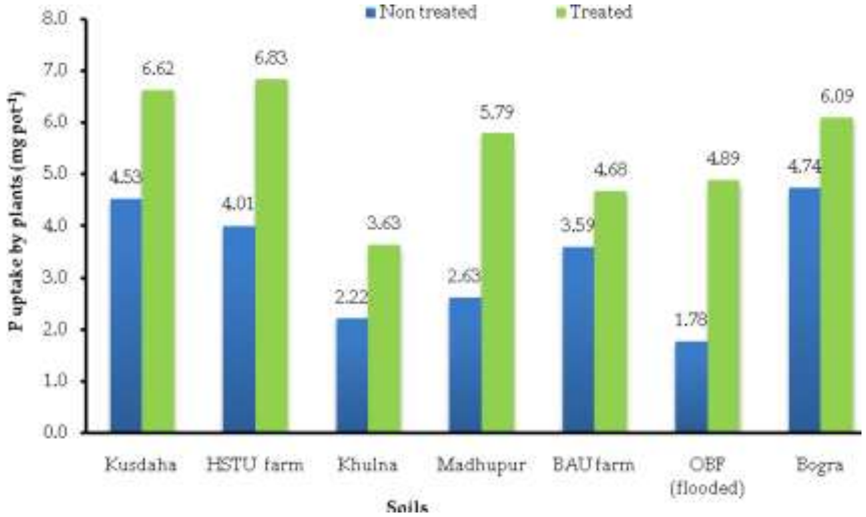

Fig. 5. Effects of P on P uptake by rice plants from different soils

Application of P in soils under incubation study increased all forms of phosphorus was highly variable across the soils under this study which was found similar to the research done by Masud *et al.* (2006). The percent increase varied from 73.38 to 1143.04% in case of labile P while Fe/Al-P, increase was 95 to 327.06%. The two OBF soils contained the higher amount of labile P than other soils. The OBF and Khulna soils were almost neutral which probably was responsible for higher percent increase in labile P. The transformation of added P to labile P was also higher in Khulna and Bogra soils because of neutral pH mainly as same as the result found by Nair and Rajasree (2004). In both OBF soils, 18% of the added P was transformed into labile P as their Ca/Mg-P was higher than other soils. The dominant cations in OBF soils were Ca^{++} and Mg^{++}, mainly responsible for highest transformation of added P to Ca/Mg-P in OBF soils. It is an established phenomenon that in acidic soils, the main form of P is Fe/Al-P (Sugito *et al*. 2001). So, the transformation of added P to Fe/Al-P was higher in Kushdaha, Madhupur and HSTU farm soils than the other soils due to their low pH or higher acidity than other soils under study. The initial Ca/Mg-P status and higher percent increase in Ca/Mg-P content indicate that the soil of Ganges Tidal Floodplain (Khulna) contained considerable amount of Ca and Mg which is mainly responsible for higher transformation of added P to Ca/Mg-P.

A considerable depletion of P was found in P treated and non-treated pots due to cropping. The depleted amount varied considerably across the soils (Narteh 2003). The used amount of different forms of P in general was higher in P treated pots than in non-treated pots. The use efficiency of labile P was the highest in all soils followed by Fe/Al-P and then Ca/Mg-P. In most of the cases, the labile P use efficiency in treated pots was more than 100%. Results indicated that the amount of added P transformation to labile P was not sufficient for the crop. As a consequence, the native labile P was also used except BAU farm and Khulna soils. A considerable amount of Fe/Al-P was also taken up by the crops but the amount was much lower than the added P which indicated that small amount of transformed Fe/Al-P remained unused in soils. The highest amount of Fe/Al-P was used from Bogra soil (92.40%) followed by HSTU farm soil. The use efficiencies of BAU farm soil and Kushdaha soil were almost similar and followed the previous soils. Water logging of soils during rice cultivation increased the availability of P due to reduction of Fe & Al oxides and due to release of P adsorbed or occluded by them (Islam *et al*. 2010). In general, more Fe/Al-P was used from acidic soils than from almost neutral soils under study. Among the acidic soils highest percent use efficiency was found in Bogra soil (92.40%) followed by HSTU farm soil (73.10%) and then Kushdaha soil (58.60%). The Fe/Al-P use efficiencies of two OBF soils were almost similar to Kushdaha soil because of its lower initial status as well as transformed amount. The use efficiency and used amount did not follow any definite trend. However, higher amount of Ca/Mg-P was used from OBF soils followed by Kushdaha and Madhupur soils. The higher percentages of Kushdaha, Madhupur and HSTU farm soils were associated with the low initial content. Lower amount of Ca/Mg-P was taken up from Bogra soil because its Fe/Al-P use efficiency was the highest (92.40%). Application of P increased the dry matter yield of rice irrespective of soils (Alam *et al*. 2009; Bilkis 2002). In general, the P effects were more significant in acidic soils such as HSTU farm, Bogra and then Kushdaha soils. The Madhupur soil is also acidic in nature but its response was lowest because of its initial Fe/Al-P and Ca/Mg-P content was higher than Bogra, Kushdaha and HSTU farm soils.

CONCLUSION

The results obtained from the incubation and pot experiment on P management effects on P fertility and yield of rice interprete that P fertilizer application into the soils increased the status of labile P, Fe/Al-P and Ca/Mg-P in soils. It was also observed that the added P was mostly transformed into Fe/Al-P in acidic soils and Ca/Mg-P in nearly neutral soils. The uptake efficiency of the labile P was the highest followed by Fe/Al-P and then Ca/Mg-P. Finally the dry matter yield and P uptake by rice (BRRI dhan28) were increased due to application of P into soils.

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